JEE Main - 2023

Physics

Answers

Section A

1. Correct Answer: D

Radius of n^{th} orbit, graph $r_n \propto n^2$ between r_n and n is a parabola. Also,

$\frac{r_n}{r_1} = \left(\frac{n}{1}\right)^2 \Rightarrow \log_e\left(\frac{r_n}{r_1}\right) = 2\log_e(n)$ comparing this equation with $y = mx + c$ Graph between $\log_e\left(\frac{r_n}{r_1}\right)$ and $\log_e(n)$ will be a straight line, passing from origin. Similarly it can be proved that graph between $\log_e\left(\frac{f_n}{f_1}\right)$ and $\log_e n$ is a straight line. But with negative slops.

2. Correct Answer: A

Acceleration, $a = \frac{Ee}{m}$ Velocity of electron, $\upsilon = at = \frac{Eet}{m}$ Wavelength, $\lambda = \frac{h}{mv} = \frac{h}{Eet}$. Now $\frac{d\lambda}{dt} = -\frac{h}{eEt^2}$

3. Correct Answer: C

Energy released $= (80\times7 + 120\times8 - 200\times6.5) = 220\,\text{MeV}$.

4. Correct Answer: A

$n_e = 8\times10^{18}/\text{m}^3, n_h = 5\times10^{18}/\text{m}^3$

$\mu_e = 2.3\frac{\text{m}^2}{\text{volt}-\text{sec}}, \mu_h = 0.01\frac{\text{m}^2}{\text{volt}-\text{sec}}$

$\because n_e > n_h$ so semiconductor is N-type

Also conductivity $\sigma = \frac{1}{\text{Resistivity}(\rho)} = e(n_e\mu_e + n_h\mu_h)$

$$\frac{1}{\rho} = 1.6\times10^{-19}\left[8\times10^{18}\times2.3+5\times10^{18}\times0.01\right]$$

$$\rho = 0.34\,\text{W.m}.$$

5. Correct Answer: A

According to given van der waals equation

$P = \frac{nRT}{V-n\beta} - \frac{an^2}{V^2}$ Work done,

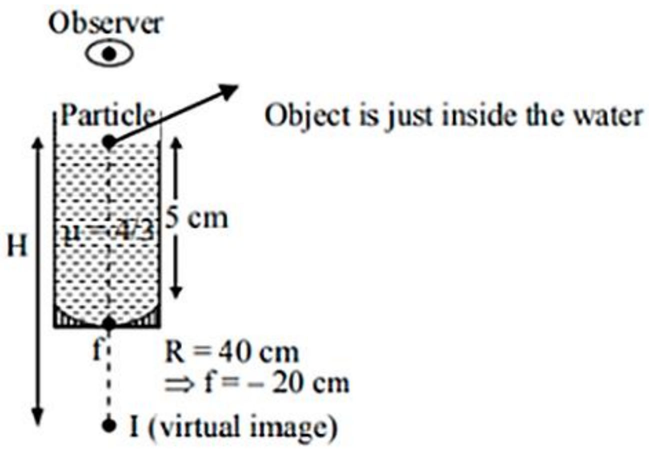
$$W = \int_{V_1}^{V_2} PdV = nRT\int_{V_1}^{V_2}\frac{dV}{V-n\beta} - \alpha n^2\int_{V_1}^{V_2}\frac{dV}{V^2} \qquad = nRT\left[\log_e(V-n\beta)\right]_{V_1}^{V_2} + \alpha n^2\left[\frac{1}{V}\right]_{V_1}^{V_2}$$

$$= nRT\log_e\frac{V_2-n\beta}{V_1-n\beta} + \alpha n^2\left(\frac{V_1-V_2}{V_1V_2}\right)$$

6. Correct Answer: B

The cyclic process 1 is clockwise whereas process 2 is anticlockwise. Clockwise area represents positive work and anticlockwise area represents negative work. Since negative area $(2) >$ positive area, (1), hence net work done is negative.

7. Correct Answer: D



$$\frac{1}{V}+\frac{1}{u}=\frac{1}{f}$$

$$\Rightarrow \frac{1}{V}+\frac{1}{(-5)}=\frac{1}{-20}$$

$$\Rightarrow \frac{1}{V}=\frac{1}{5}-\frac{1}{20}$$

$$\Rightarrow \frac{1}{V}=\frac{4-1}{20}=\frac{3}{20}$$

$$\Rightarrow V=\frac{20}{3}\text{cm}$$

$$H=5+\frac{20}{3}=\frac{35}{3}\text{cm}$$

$$H_{\text{apperent}}=\frac{H}{\mu}=\frac{\left(\frac{35}{3}\right)}{\left(\frac{4}{3}\right)}$$

$$=\frac{35}{3}\times\frac{3}{4}=\frac{35}{4}=8.8\,\text{cm}$$

8. Correct Answer: A

$$m=\frac{I}{O}=\frac{f}{u-f}=\frac{10}{25-10}=\frac{10}{15}=\frac{2}{3}$$

$$m^2=\frac{A_i}{A_o}\Rightarrow A_i=m^2\times A_o=\left(\frac{2}{3}\right)^2\times(3)^2=4\,\text{cm}^2$$

9. Correct Answer: D

Position of 10^{th} maxima $=\frac{10\lambda D}{d}=3\,\text{cm}$ (w.r.to central maxima)

$$\frac{\lambda D}{D}=\frac{3}{10}\text{cm}$$

New fringe width $=\frac{3}{10\times\mu}$

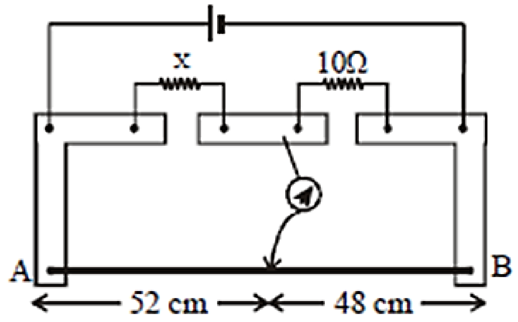
Now positive of 10^{th} maxima $=\frac{3}{10\times1.5}\times10=2\,\text{cm}$

Position of central maxima $=2\,\text{cm}$

10^{th} maxima $=4\,\text{cm}$

10. Correct Answer: B

At Null point



$$\frac{X}{\ell_1}=\frac{10}{\ell_2}$$

Here $\ell_1 = 52 + \text{End correction} = 52 + 1 = 53\,\text{cm}$

$\ell_2 = 48 + \text{End correction} = 48 + 2 = 50\,\text{cm}$

$\therefore \frac{X}{53} = \frac{10}{50}$ $\therefore X = \frac{53}{5} = 10.6\Omega$

11. Correct Answer: D

Resistance of bulb $R_b = \frac{(1.5)^2}{4.5} = 0.5\Omega$

Current drawn from battery $= \frac{E}{2.67 + 0.33} = \frac{E}{3}$

Share of bulb $= \frac{2}{3} \times \frac{E}{3} = \frac{2E}{9}$

$\therefore \left(\frac{2E}{9}\right)^2 \times 0.5 = 4.5$ or $E = 13.5V$

12. Correct Answer: C

$\alpha(T) = \frac{1}{R_0}\frac{dR}{dT}$ or $\left(3T^2 + 2T\right) = \frac{1}{R_0}\frac{dR}{dT}$ or $dR = R_0\left(3T^2 + 2T\right)dT$ or

$\int_{R_0}^{R} dR = R_0\left[3\int_0^T T^2 dT + 2\int_0^T T dT\right]$ or

$R = R_0\left[1 + T^2 + T^3\right]$

13. Correct Answer: D

$\oint \vec{E} \cdot \vec{A} = EA\cos\theta$, this value can be zero, if either E is zero or $\theta = 90°$. But it must show that net charge inside close surface is zero.

14. Correct Answer: B

The two capacitors are in parallel so

$$C = \frac{\varepsilon_o A}{t \times 2}(k_1 + k_2)$$

15. Correct Answer: C

The magnetic field of two equal half's of the loop is equal and opposite and so $\vec{B} = 0$.

16. Correct Answer: C

Magnetic field in solenoid $B = \mu_0 ni$

$$\Rightarrow \frac{B}{\mu_0} = ni$$

(Where $n =$ number of turns per unit length)

$$\Rightarrow \frac{B}{\mu_0} = \frac{Ni}{L}$$

$$\Rightarrow 3 \times 10^3 = \frac{100i}{10 \times 10^{-2}}$$

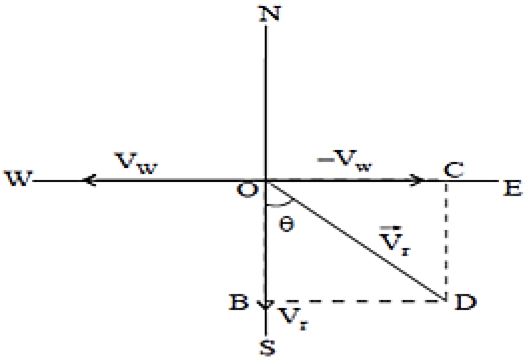
$$\Rightarrow i = 3\text{A}$$

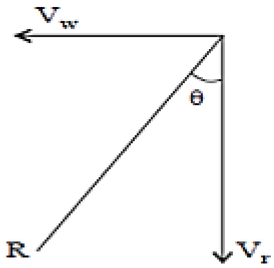
17. Correct Answer: D

In, $1 - \upsilon^2, \upsilon^2$ should be dimensionless, so it should be $1 - \frac{\upsilon^2}{c^2}$

18. Correct Answer: A

Man should hold the umbrella in the direction of the relative velocity of the rain. If $Vr \rightarrow$ velocity of rain, $Vw \rightarrow$ velocity of wind and $V_{rw} \rightarrow$ relative velocity of rain w. r. t. wind





$\therefore \quad \tan\theta = \frac{\bar{V}_w}{\bar{V}_r}$

19. Correct Answer: A

Given energy density $= 50\,\mathrm{W/m^2}$

Here, change in momentum $\Delta p = p_f - p_i$

$$\Delta p = \left(\frac{-p_i}{4}\right) - p_i$$

$$\Delta p = \frac{-5p_i}{4}$$

$\because\ p_i = I/c = 50/\left(3\times10^8\right)$

$$\frac{\Delta p}{\Delta t} = F = \left|\frac{-5p_i}{4}\right| = \left(\frac{5}{4}\right)\times\left(\frac{50}{\left(3\times10^8\right)}\right) = 20.8\times10^{-8}\,N \approx 20\times10^{-8}\,N$$

20. Correct Answer: A

In semiconductors, by increasing temperature, covalent bond breaks and conduction hole and electrons increase.

Section B

21. Answer: 4

Let, the charge on the inner sphere is q_A

Now, potential on the inner sphere due to charge q and q_A will be,

$$V_m = \frac{q_A}{4\pi \in_O a} + \frac{q}{4\pi \in_O (4a)}$$

The inner sphere is grounded; hence its potential is zero. So,

$$V_m = O$$

$$\Rightarrow \frac{1}{4\pi \in_0} \frac{q_A}{a} + \frac{1}{4\pi \in_0} \frac{q}{4a} = 0$$

$$\Rightarrow \frac{q_A}{a} = -\frac{q}{4a}$$

$$\therefore q_A = -\frac{q}{4}$$

Comparing with the data given in the question, we get $n = 4$

22. Answer: 7J

By the first law of thermodynamics

$$Q = \Delta U + A$$

But $\Delta U = \frac{p\Delta V}{\gamma - 1} = \frac{A}{\gamma - 1}$ (as p is constant)

$$Q = \frac{A}{\gamma - 1} + A = \frac{\gamma A}{\gamma - 1} = \frac{1.4}{1.4 - 1} \times 2 = 7\,\text{J}$$

23. Answer: 16 N

Step 1

Acceleration a of system of blocks A and B is

$$a=\frac{\text{Net force}}{\text{Total mass}}=\frac{F-f_1}{m_A+m_B}$$

Where, $f_1 =$ limiting friction between B and the surface

$$=\mu\left(m_A+m_B\right)g$$

So,

$$a=\frac{F-\mu\left(m_A+m_B\right)g}{\left(m_A+m_B\right)}$$ ....(i)

Here, $\mu=0.2, m_A=1\text{kg}, m_B=3\text{kg}, \text{g}=10\,\text{ms}^{-2}$

Substituting the above values in Eq. (i), we have

$$a=\frac{F-0.2(1+3)\times 10}{1+3}$$

$$a=\frac{F-8}{4}$$ ....(ii)

Due to acceleration of block B, a pseudo force F' acts on A

Step 2

This forces F' is given by

$$F'=m_A a$$

Where, a is acceleration of A and B caused by net force acting on B.

For A to slide over B; pseudo forces on A, i.e. F' must be greater than limiting friction

Between A and B.

$$\Rightarrow m_A a \geq f_{l_2}$$

We consider limiting case,

$$m_A a = f_{l_2} \Rightarrow m_A a = \mu\left(m_A\right)g$$

$$\Rightarrow a=\mu g = 0.2\times 10 = 2\text{ms}^{-2}$$ ....(iii)

Putting the value of a from Eq. (iii) into Eq. (ii) we get

$$\frac{F-8}{4}=2$$

$$\therefore F=16\,\text{N}$$

24. Answer: 9 m

Acceleration of COM

$$a_{\text{com}}=\frac{F}{m+2m}=\frac{F}{3m}$$

$$\therefore X_{\text{com}}=\frac{1}{2}a_{\text{com}}t^2=\frac{F}{6m}t^2 \quad \text{............(i)}$$

Let displacement of the heavier block at t is x'

Further $x'_{\text{com}}=\frac{m(x)+2m(x')}{m+2m}$

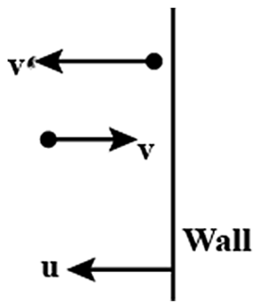
$$X'_{\text{com}}=\frac{x+2x'}{3} \quad \text{...........(ii)}$$

From equation (i) and (ii).

$$X_{\text{com}}=X'_{\text{com}}$$

$$\Rightarrow x'=\frac{Ft^2}{4m}-\frac{x}{2}=\frac{10\times 4}{4\times 1}-\frac{2}{2}=9\,\text{m}$$

25. Answer: 9



e = 1

Given: Coefficient of restitution $e=1$

Speed of the wall $u=3\,\text{ms}^{-1}$

Velocity of the ball before collision $v = 3\text{ms}^{-1}$

Let the speed of the particle after collision be v'

Using $\frac{v'-u}{-v-u} = -e$

$\frac{v'-u}{-v-u} = -1$ $\Rightarrow v' = v + 2u$

$\therefore\ v' = 3 + 2(3) = 9\,\text{ms}^{-1}$

26. Answer: 3

Moment of inertia is minimum at the centre of mass of the body.

For $'l'$ to be minimum

$\frac{dl}{dx} = 0 \Rightarrow \frac{d\left(2x^2 - 12x + 27\right)}{dx} = 0$

Now differentiate with respect to x,

We get

$\Rightarrow 4x - 12 = 0$

$x = \frac{12}{4} = 3$

$x = 3,$ hence the x- coordinate of COM is 3

27. Answer: 1

$T = \frac{1}{2} m_0 \left(\sqrt{\frac{GM}{R}}\right)^2$

$T = \frac{GMm_0}{2R}$

$T \alpha \frac{m_0}{R}$

$$\frac{T_A}{T_B} = \left(\frac{R_B}{R_A}\right)\left(\frac{m_{0A}}{m_{0B}}\right)$$

$$\frac{T_A}{T_B} = \left(\frac{2R}{R}\right)\left(\frac{m}{2m}\right) = 1$$

28. Answer: 90

Bigger pendulum (greater (l)) will have greater time period.

Time period of smaller pendulum $T_1 = T$

Time period of bigger pendulum $T_2 = \frac{5T}{4}$

They both start at the same time from mean position, after time t, phase difference between them is:

$$\Delta\phi = \omega_1 t - \omega_2 t = \left(\frac{2\pi}{T} - \frac{2\pi}{5T/4}\right) \times t$$

When bigger pendulum completes oscillation, $t = \frac{5T}{4}$

$$\Rightarrow \Delta\phi = \frac{2\pi}{5T} \times \frac{5T}{4}$$

$$\therefore \Delta\phi = \frac{\pi}{2} = 90^\circ$$

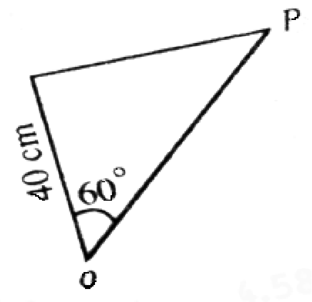
29. Answer: 40 cm

OP is the Portion of the rod immersed in water.

$$\cos 60^\circ = \frac{40}{OP}$$

$$OP = \frac{40}{\cos 60^\circ}\,\text{cm} = \frac{40}{\frac{1}{2}}\,\text{cm} = 80\,\text{cm}$$

The centre of buoyant is at the centre of the immersed part of the rod. So, the required distance is $40\,\text{cm}$.



30. Answer: 3

ϕ (flux linked)

$= a^2 B\cos 0° + b^2 B\cos 180°$

$= \left(a^2 - b^2\right) B$

$E = -\frac{d\phi}{dt} = -\left(a^2 - b^2\right)\frac{dB}{dt}$

$= \left(a^2 - b^2\right) B_0 \omega \cos \omega t$

Where $B = B_0, \sin \omega t, B_0 = 10^{-3} T, \omega = 100$

$\therefore I_{\max} = \left(a^2 - b^2\right)\frac{B_0 \omega}{R}$

and: $I_{\max} = \frac{(a-b) B_0 \omega}{4r} = \frac{(1-0.4)\times 10^{-3}\times 100}{4\times 5\times 10^{-3}} = 3A$